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ABSTRACT

The Radio Mathematics Project was funded by the Agency for International Development to design, implement, and evaluate, in conjunction with personnel of a developing country, a system for teaching primary-grade mathematics by radio. In July 1974, a project in Nicaragua began with a series of radio presentations, each followed by 20 minutes of teacher-directed activities. No textbooks were used; a worksheet was followed during the broadcast and oral and physical responses were given. Songs and games were included in the programs for a change of pace, but unembellished mathematical work also kept the children's attention. Provisions were also made for initial and continuing teacher training, testing and evaluation, and revision of the program. (DS/LS)

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# THE NICARAGUA RADIO MATHEMATICS PROJECT

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INSTITUTE FOR MATHEMATICAL STUDIES IN THE SOCIAL SCIENCES

STANFORD UNIVERSITY

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# THE NICARAGUA RADIO MATHEMATICS PROJECT

The Institute for Mathematical Studies in the Social Sciences at Stanford University has been funded by the Agency for International Development (AID) to investigate the teaching of primary school mathematics by radio. The Technical Assistance Bureau of AID has in the past supported several investigations of the use of instructional television in developing countries. It is now turning to radio as a potentially cheaper means of applying technology to the problems of providing mass primary education in countries too poor to expand the traditional school system. In funding the Institute AID is hoping to learn more about the use of radio for instruction.

The thrust of our work is to improve the quality of instruction in the classroom, not to replace the teacher with a cheaper alternative. We are looking for ways to inprove the efficacy of radio as an instructional tool and we expect that if we are successful, others can use our work to develop lessons for non-school populations, or in programs that replace teachers with classroom monitors.

Our strong concern with instructional efficacy is probably the chief difference between the Stanford project and others that have used radio for instruction. The intent of many instructional radio programs in mathematics has been to illustrate the applicability of mathematics to everyday life, or to present enjoyable stories with mathematical content that the writers hope will stimulate interest in mathematics. We have found to date no discussion in the

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research literature of ways to organize curriculum materials for systematic instruction by radio.

The closest parallel to our efforts is the TV program Sesame Street, and we have learned much from the work of the Children's Television Workshop (CTW). However, Sesame Street differs from our radio programs in three important ways. First, of course, is the availability of the visual component provided by TV. Second, Sesame Street is forced to capture its audience, and the potential audience is quite a sophisticated one. Therefore, the program must employ sophisticated techniques for attracting and maintaining the attention of the children. The children we work with have no choice about listening to our program, but their alternative is listening to the teacher. Moreover, although they are familiar with radio programs, it is unlikely that any of them has heard a program written specifically for children. Thus, although we would like children to enjoy the radio lessons, we don't have the same requirements for attention-getting.

The third and perhaps most important difference between Sesame Street and our project is our goal of providing sequential instruction. Sesame Street programs are written so that understanding one segment does not depend on having viewed a previous one. In contrast, we are designing an instructional program that explicitly uses earlier lessons as prerequisites for later ones. I plan to discuss at some length our present ideas about the development, tryout, and revision of curriculum, but first let me describe more generally what we're doing and where we're doing it.

The project is located in Nicaragua, in the Department of Masaya near the capital city of Managua. The department has one large and

several small municipalities. Roughly two-thirds of the primary school population of 18,000 attends school in these urban areas. The remainder attend rural schools, which, perhaps because of the small size of the department, do not seem to be substantially different from the urban schools. Approximately 37 percent of the urban primary school population is in first grade, and this figure rises to 46 percent for the rural school population. The ages of a randomly-selected sample of 874 first-grade students range from 5 to 14 years, with a mean age of 8.2 for urban students and 8.5 for rural students. The schools of Masaya have many of the typical characteristics of primary schools in developing countries--high dropout and repetition rates, a wide spread of age levels in each grade, and rural school attendance records that are related to farming activities.

The project is administratively part of the Nicaraguan Ministry of Education, in a newly formed division for research and evaluation. About ten years ago the Ministry participated in a joint project of the Central American countries to write new primary school textbooks. Following that effort, Ministry personnel undertook a thorough revision of the primary school curriculum. One of the Nicaraguan authors of the mathematics text series, Mrs. Vitalia Vrooman, subsequently supervised the mathematics curriculum revision effort for the Ministry. She is now Nicaraguan director of our project.

The Nicaraguan government has, from the outset, been enthusiastic about the project, and has provided personnel, office space, and furniture through the Ministry budget. On a day-to-day basis our closest contact is with the School Inspector for the Department of Masaya. He has been extremely cooperative, arranging

access to schools for both testing and radio lessons, and supplying us with whatever data he has available.

The project office opened in Masaya in July, 1974, and we began work in schools in the latter part of the year. The Nicaraguan school year extends from February to November. In October, 1974, near the end of the school year, we administered a project-designed achievement test to approximately 1200 first-grade students. We began a pilot mathematics program in 16 first-grade classrooms at the beginning of the school year this past February, using tape recorders to simulate the presentation of recorded radio lessons.

The project assumes responsibility for all of the mathematics instruction children receive. Each daily lesson consists of a twenty-minute radio presentation, followed by approximately twenty minutes of teacher-directed activities. No textbooks are used (most of the classrooms do not have any) and the amount of printed material distributed by the project is limited to one page per student per day. Most frequently the supplementary paper is in the form of a student worksheet, which is used during the broadcast at the direction of the instructional program. Worksheets are printed and distributed by the project, which also occasionally supplies other materials, such as rulers printed on cardboard. Teachers are asked to provide additional inexpensive materials such as bottle caps, sticks, or numeral cards.

During the radio lesson, children are asked to respond orally, physically, and in writing, and they do so from 40 to 60 times in each twenty-minute lesson. Oral responses include answers to arithmetic exercises and other questions asked by radio characters, and singing.

Among the physical responses are games and exercises, working with concrete materials, and pointing to pictures or numbers on the worksheet. Written responses are almost all on the worksheet, although we are experimenting with having students use their own notebooks.

The project provides direction to teachers by means of a guide that accompanies each lesson. The teacher plays a limited role during the broadcast portion of the lesson, mostly helping the slower children with written work. After the broadcast she presents the remainder of the project lesson, which has been specified in the guide. Teachers use the guide in different ways; some follow it closely, often reading portions of it to the class, while others use it as a source of suggestions for a lesson they design themselves.

For the first month of the present school year we provided weekly teacher training sessions. Since then the teachers have met once every six weeks. Each teacher sees a project staff member at least once a week when lesson materials are delivered, and thus has a regular opportunity to ask questions and register complaints. The teachers this year are cooperating well with the program, and have been for the most part accepting and even enthusiastic.

Our experimental classrooms are distributed among urban and rural schools. Some of the classrooms have only first-grade students, others have students at two or three grade levels. Although all of the teachers participating during the present pilot testing phase are doing so voluntarily, we attempted to enlist teachers with differing levels of experience and competence.

Student worksheets are collected from all sixteen classrooms, and they are used as a source of performance data. In addition, in

six classrooms the mathematics lesson is observed daily by project staff members, who complete rating sheets covering both general aspects of the lesson and specific questions posed by the lesson developers. This system of observation provides immediate feedback to the curriculum specialists and radio script writers and allows for much informal experimentation with teaching techniques.

In order to obtain systematic measures of student progress we designed tests that were presented weekly during the regular radio lesson. We deliberately disguised the tests (calling them reviews) because we thought teachers might either resent the evaluation efforts or help the children to do well. The tests turned out to be almost useless fpr evaluation purposes, for another reason entirely. The level of cooperative answering in the classroom was so high that we were unable to obtain statistically reliable information from the analysis of any worksheet data, including the tests. There is sufficient variability in mean scores to indicate the relative difficulty of exercise types, but we are unable to reliably measure individual student progress or to estimate group achievement levels.

We have since instituted weekly paper-and-pencil tests, which are proving to be much more useful. The tests are administered by staff members in a standard testing situation, with strenous efforts made to reduce copying and teacher interference. By using a matrix-sampling design, in which not all students work all exercises, we are able to obtain information on 50 items each week. The population of students and the universe of 50 items are both divided into five groups, and each student takes a test of ten items. Tests are hand scored and the results are available almost immediately.

The results of classroom observations, examination of worksheets and performance data from weekly tests are being used develop guidelines for lesson revision. According to our present schedule, we will broadcast first-grade lessons (partly revised) during the 1976 school year, using the facilities of a local radio station. The full year's lessons, about 150 of them, will be broadcast to fifty classrooms. Initial development and pilot testing of second-grade lessons will proceed simultaneously, using the same level of observation and data collection as was used for first grade.

For each grade level, the evaluation conducted during the pilot testing year will be almost exclusively formative, focusing attention on student attainment of the project's instructional goals. During the next year, when lessons are delivered by radio, project evaluation efforts will be more summative in character. Classes will be randomly assigned to treatments (control and experimental), and we will attempt to assess the effect of the radio instructional program in comparison with traditional instruction. Since project lessons are based on the mathematics curriculum designed by the Nicaraguan Ministry of Education, both experimental and control classes can be expected to have studied roughly the same material during the school year, allowing for a comparison of mathematics achievement of the two groups.

As an additional method of comparing achievement, the project will examine teacher evaluations of student performance (which are usually based on a teacher-constructed year-end test) and compare repetition rates due to failure in mathematics for control and experimental students. A more broadly based examination of dropout

rates is also planned, as a component of an analysis of the economic consequences of the use of radio for instruction in this setting.

I will leave further discussion of these general aspects of the project to the question period and turn now to a more detailed examination of the process of curriculum development and revision.

Our approach to curriculum development reflects the long history of research in computer-assisted instruction (CAI) that has been the main focus of Institute activity under the direction of Patrick Suppes. Our CAI work influences our point of view about the structure of radio lessons in several ways. First, we think that the high level of responding characteristic of a student's interaction with the computer is both engaging and motivating, and we have sought to design radio lessons that call forth a similar high level of student activity.

Second, we have had success with lesson formats that provide a variety of exercise types during a single lesson (and there is support in the research literature for the effectiveness of this mode of practice). We therefore construct each radio lesson as a series of independent segments of different character, rather than devoting each lesson to a single topic. We try to build into the lessons variety in both topics and response modes.

Our CAI experience has also influenced our conception of the structure of the curriculum. We have found it useful to view the curriculum content as partitioned into separate topics (which we call strands), with the development of each strand described independently of the others, even though the strands are of course related.

For drill-and-practice programs in elementary mathematics we

further partition a strand into equivalence classes of exercises, each of which is defined in terms of structural aspects of the exercises it contains. (For example, all vertical addition problems with two addends and sum less than 10 might constitute a single equivalence class.)

For our present project, which provides instruction as well as practice, we have modified this structure, replacing the non-overlapping equivalence classes by sets of nested instructional classes. Continuing with our vertical addition example, the first class in a set might contain exercises with sums up to four, in the next class the limit would be extended to five, and so on. At some point, as the upper limit increases, the earlier exercises (sums to four) will no longer be included for instruction (although those exercises will be available for review) and the limits for the next instructional class will be truncated at the lower end. Sets of classes of this type are defined for each topic within a strand, and each class specifies the mathematical content of a lesson segment.

We have worked with this method of organizing the curriculum long enough to know that we can apply it to constructing radio lessons. In order to further systematize our conception of the process of curriculum development and revision, we propose the following model, which embodies the lesson structure I have just described.

We view lesson development as based on a group of factors of increasing levels of specificity each of which can be parameterized. The initial curriculum design entails choosing initial values of the parameters, and the revision task is that of choosing which parameter values to change and how to change them. The model we propose has five levels, shown schematically in Figure 1.

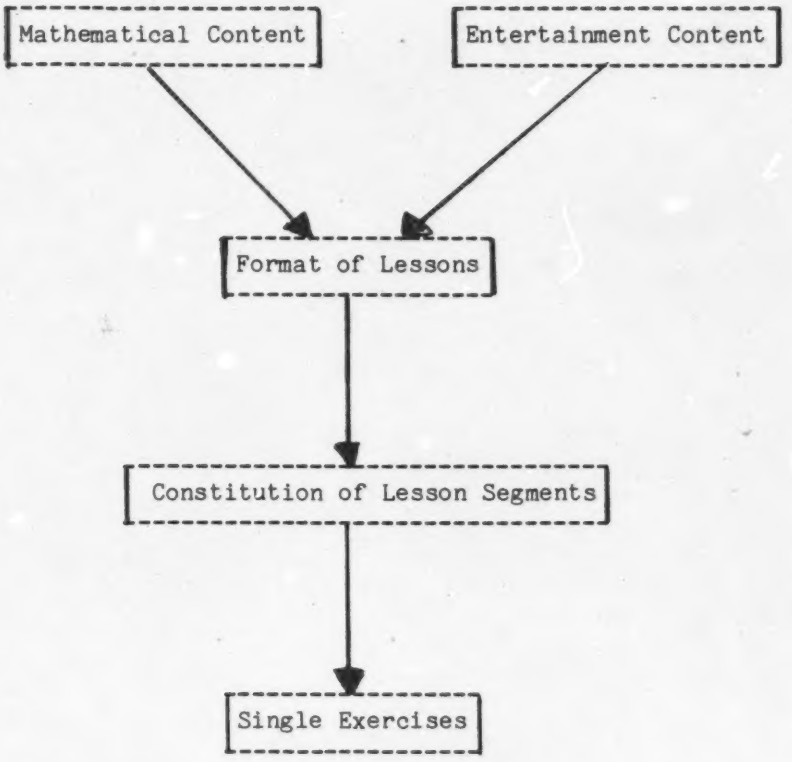


Figure 1. Model of curriculum development.

First, let me say something about the separation of mathematical content and entertainment content. At issue is a fundamental question that I'll phrase somewhat flippantly; Do we consider entertainment to be the coating on the pill or the frosting on the cake? Many people seem to feel that the pill of mathematics must be coated to make it palatable. Our experience to date with radio lessons, which confirms our earlier CAI work, is just the opposite. When young children are given the opportunity to respond actively, they give every appearance of being attentive to and interested in mathematical tasks.

Basically, we view the entertainment as providing a change of pace--a chance to exercise or sing or laugh. We do not feel that there must be a clear separation between entertainment and instruction --we often present mathematics entertainingly, and many games, songs, jokes and stories have mathematical content. However, we know from experience that we can present unembellished mathematical work and keep the attention of the children.

We have not yet had much success with using stories, either for entertainment or instruction, and we're not sure why. The children clearly prefer activities, whether mathematical or not, to listening to stories. Since we think children generally like stories, we expect that we have not yet tuned into their lives enough to learn what interests and attracts them. In any case we would probably not use the kind of leisurely mathematical story often presented in radio mathematics lessons; such stories ask the children to respond five or ten times in the course of a 20-minute lesson. Our lessons are much faster paced. Typically, first graders listening to radio lessons are responding to 30 or 40 exercises in a comparable time period.

Turning back to the model, let's consider the most general level, mathematical content. The appropriate parameters are (a) the scope of topics (which instructional classes to include), (b) the instructional sequence within each topic (how to define the instructional classes and what order they should appear in), and (c) the balance among topics (what proportion of instructional time is allotted to each topic).

In our present situation the scope of topics is delimited by the specifications of the Nicaraguan curriculum guide. For two reasons, this is not a constraint. First, there is great commonality in primary school mathematics curriulums around the world, and the revised Nicaraguan curriculum is very similar to what might be specified anywhere, including the United States. Second, the Nicaraguan curriculum guide follows the trend in the United States and elsewhere towards broadening the scope of the curriculum, and actually contains more topics than we want to teach at the first-grade level.

I'd like to add a remark about this second point. In the United States, at least until very recently when there seems to be a move to 'return to fundamentals', the tendency has been to increase the variety of topics taught, with the expectation that exposure to many topics will increase children's flexibility in understanding and using arithmetic. The proponents of this position have either not attended to the concomitant necessity to reduce practice on each topic, or have assumed that smaller amounts of practice with many types of exercises will produce at least the same degree of computational and conceptual competence as more practice with fewer types of exercises.

We're not sure this is the case. We prefer to define a

relatively limited set of instructional objectives that represent the skills that the staff--Nicaraguan and American--thinks all children should acquire in first grade. For the first-grade curriculum now being developed there are 23 such minimal objectives, drawn from five strands--number concepts, addition, subtraction, measurement, and applications. Another 17 advanced objectives cover topics presented for enrichment and for the more able students.

For each objective we develop a teaching sequence--that is, we define the set of instructional classes that we expect will lead to student attainment of the objective. The teaching classes may be quite different from the terminal performance expected. For example, the first instructional class for vertical addition teaches the children to draw the appropriate number of circles next to a numeral. The next class teaches them to draw circles next to each addend, count the circles, and write the appropriate numeral below the line. Then, the children are instructed to use this algorithm for finding sums, which they do until they have committed the basic combinations to memory.

Among the quantitative decisions that must be made in defining the appropriate instructional classes are the size of the incremental steps used to define nested classes, the range of exercises in a class (that is, where to truncate at the lower end), and the ordering of related topics within a strand. Two further decisions must be made; how to mesh topics from different strands, and how to allocate instructional time to different strands and topics within strands. Initially we make these quantitative decisions using the intuition and experience of both Nicaraguan and American staff members. A major goal of our project is to develop systematic ways of revising these

initial decisions on the basis of pilot testing of lessons.

Returning to the model, the parameters relevant for entertainment content are, (a) the proportion of time spent on entertainment, and (b) the frequency of use of each type of entertainment segment. At present we have successfully used songs and physical games, and we are experimenting with the use of jokes, riddles, jingles, guessing games, and other short episodes that are not in story form. Some of the songs are about mathematics and almost all of them are written and recorded specifically for the project by staff members and local musicians.

We are still actively experimenting with types of entertainment. Each lesson usually has at least one song and one physical game. Beyond that I cannot provide any general principles, primarily because our experience has differed so strongly from our expectations. We assumed that children would enjoy stories, and that these would constitute the major type of entertainment we would use. It took us quite a while to acknowledge that we were wrong (at first we made many changes in the format and content of the stories) and now, halfway through the school year, we are substantially revising our approach to providing entertainment.

Next we'll look at the parameters that describe the format of a single lesson. These are (a) the total number of segments in a lesson (during and after the broadcast), (b) the length of individual segments, (c) how many segments of each type, (d) the ordering of segments within the lesson, and (e) the character of transitions.

Our basic assumption about the order of segments within a lesson is--the more variety the better. Instructional segments can differ in content and in response mode, and we vary both of these

as much as possible in each lesson. We also avoid having two successive segments of the same type (with respect to content and response mode). We might, for example follow an oral addition segment with an oral subtraction segment, or a written addition segment, but not with another oral addition segment.

Experience has led us to develop certain constraints on what otherwise might be an almost random order of segments. First, we find that materials distributed to children for use during the broadcast cause less distraction if they are used right away; when children have sticks or bottle caps on their desks they are less likely to fool around with them if they have already had a chance to use them. Therefore, in general we use materials at the beginning of the lesson.

The student worksheets are also enticing. Once students have started using them, they continue to draw or work exercises unless their attention is thoroughly diverted. So, all worksheet activities go at the end of the radio lesson, interrupted only by songs or physical games.

At present we use from six to ten instructional segments and two to four entertainment segments. Typically, two or three of the instructional segments are taught by the teacher, the remainder by the radio.

I could complete a description of the model, giving increasingly specific details about segments and exercises, but I think by now I've given a reasonably clear picture of our type of approach to lesson development.

I'd like to talk briefly now about revision. Our ideas about the revision process are less well formulated than about the initial

construction of curriuclum. We tend to use the word revision ambiguously to refer to change occurring at two quite different times. First, we refer to changing a lesson that has been written and pilot tested. The lesson will not be used again until the following school year, and thus the effects of the revision are not felt until a year later. However, we can use the results of data gathered for revision on a much shorter time scale. Our production schedule is set up so that we can and do use results of pilot testing of lessons to change the plans for future lessons during the same school year.

The production process starts with a final lesson structure in the form of an outline of lesson segments. From this the radio script and the teacher's guide are written and the worksheet is drawn. The lesson is recorded and put on a cassette, the written materials are mimeographed and all of these materials are distributed to teachers. About one month elapses between the time a final lesson structure is adopted and the lesson is tried out in the classroom.

Out of our experience this year we are developing more systematic ways of organizing the revision process, based on our model of curriculum development. To date, most of our work has concerned the second type of change I described, altering plans for future lessons. I'll describe two cases in which information we gathered influenced future curriculum development and then indicate how we hope to make the process more systematic.

The first example concerns mathematical content, which perhaps you recall, is the top level of the model I described earlier. The parameter involved is the number of instructional segments needed to teach the concept 'more or less' as a readiness topic for the more

advanced topic of 'greater or lesser.' The first type of exercise typically shows two sets of objects and students are asked to indicate which set has more objects. 'Greater and lesser' exercises ask the student to compare numbers. The curriculum plan called for 20 segments (with a total of 100 exercises) to teach 'more or less.' The first time these exercises were given, the performance level on worksheets was 98 percent correct. Even given the unreliability of the worksheet data this was a good indication that most children were quite familiar with the concept and classroom observations confirmed this. As a result we cut the number of instructional segments from 20 to eight. (In a complete revision we will reduce the number of segments to four.)

The second example concerns the time allowed for responding to each type of exercise. Each time we introduce a new type of exercise we give instructions to the classroom observers to note the response patterns of the children. We think that if anyone is still responding (writing or speaking) when the time is up, the time should be increased. On the other hand, if everyone has finished responding one or more seconds before time is up, the time should be decreased.

Generalizing from these examples (and others like them) we can list four steps in collecting and using information for curriculum change.

1. Decide what type of information must be collected in order to make a decision about the need for a change in a parameter value.
2. Establish a criterion for the decision to change a parameter value.
3. Collect the necessary information.
4. If a change is required, specify the size and direction of

the change.

The first step is the most important, and must be done while the lesson is being planned, not after the fact. That is, we need to identify the types of information that will allow us to make decisions about changing parameter values before the lesson is given. We must be sure that provision has been made for collecting the relevant information. In some cases the requirement for information will affect the specifications for the lesson, and classroom observers must be told what to look for when the lesson is presented. In other cases, the need for information will specify the content of the paper and pencil tests given each week. The presentation of a lesson, then, will serve two purposes, each of which has been systematically planned: the lesson will give instruction, of course, but at the same time the observatios made during its presentaion will provide the data needed for revision of the same lesson in the following year and for the construction of later lessons the same year.

Why have I chosen to talk in such detail about curriculum development and revision? Well, first, because I can't answer the question everyone is interested in--how well are we succeeding in teaching children by radio. We think we are doing well, but at present we have only testimonials, no data. We will have preliminary results at the end of this first school year in November, but no experimental comparisons until the end of 1976.

But second, I have chosen to talk about curriculum because it seems to me that it is the most neglected aspect in reports of media projects, especially those carried out in developing countries. What children learn, after all, depends very largely on what and how we

teach them. We have a great deal to learn about how to structure, organize, and present didactic material in a way that maximizes student learning. We view our project as a step in that direction.